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Impacts of the Triple Global Crisis on Growth and Poverty in Yemen

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ABSTRACT

Yemen is an oil-exporting and food-importing country on the Arabian Peninsula with persistently high levels of poverty. The impacts of the food, fuel, and financial global crises are likely to further complicate preexisting conditions of internal conflicts, decreasing oil revenues, and governance failure. The latest official growth numbers date back to precrisis levels; new estimates are subject to much debate; and the current state of poverty in Yemen remains unclear. In this paper, a consistent economic framework is presented to help close this information gap and to better understand growth and poverty dynamics during crises. Results show that economic growth in Yemen accelerated during the food and fuel crises in 2008 because oil-driven growth dominated the negative growth impacts of the food crisis. However, this oil-driven growth has not been pro-poor; in fact, poverty in both rural and urban areas rises sharply in 2008. The financial crisis in 2009 impacts Yemen mainly through the drop in oil prices and a reduction in remittances and thereby sharply slows growth, including agricultural growth. This growth decline hits households hard and compounds the poverty effects of the food crisis. Model results indicate that poverty has increased to 42.8 percent in 2009, an increase of 8 percentage points from 2005–2006, when it was 34.8 percent. Poverty continues to be much higher in rural areas, where almost half of all people lived in poverty in 2009, compared with 29.9 percent in urban areas. These estimates can be considered conservative because we do not account for conflicts and natural disasters that recently hit the country.

Keywords: global economic crises, conflict, growth, poverty, Yemen

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1. INTRODUCTION

Despite early signs of a global recovery, scattered evidence suggests that many developing countries might have lost years of previous economic growth and poverty reduction gains. In fact, developing countries have been hit twice during the past two years. The food and fuel crises of 2007–2008 have led to spiking inflation, deteriorating current account balances, and increasing government deficits in many countries. Due to high food and fuel prices, 132 million people might have fallen back into poverty (Ivanic and Martin 2008). By mid-2008, a sharp reversal from the food and oil price spikes tamed inflation and sparked hope for a quick recovery. Then the financial crisis, in development since the end of 2007, turned into a global recession by the end of 2008. In 2009 it became clear that sharply shrinking global trade, foreign direct investments, remittances, and tourism receipts would make a quick recovery elusive in most developing countries. Not only are many developing countries highly dependent on these sources of income, but they also often lack the resources to effectively respond to crises and cushion the negative impacts through fiscal stimulus and other measures. Chen and Ravallion (2009) estimate that 64 million people will fall into poverty as a consequence of the financial crisis in 2009 (using the \$2.00/day threshold). The United Kingdom's Department of International Development (DFID) estimates that 90 million additional people will be poor by the end of 2010 (using the \$1.25/day poverty line) (McCord and Vandermoortele 2009).

There is broad agreement on the main channels through which the food, fuel, and financial crises affect developing countries (World Bank 2008; Ivanic and Martin 2009; Jones et al. 2009). Yet, the developmental impact of each of these crises and how these impacts might have affected each other is not well understood. In addition, impacts are likely to differ widely between different countries due to large differences in fiscal, trade, economic, and household structure.

This paper considers Yemen, a net exporter of oil, a net importer of food, and one of the poorest countries in Asia. Before the series of crises hit Yemen, its government had prepared an ambitious five-year plan with the main objectives of accelerating economic growth to 7.1 percent (from 3.8 percent between 2000 and 2006) and reducing poverty to 19.8 percent by 2010 (from 34.8 percent in 2005–2006) (MOPIC 2006). By 2007, the country had made some progress on the economic reforms envisaged to achieve these goals, including civil service and public financial management (PFM) reforms, adjustments to fuel subsidies in 2005, and improvements to the social safety net (IMF 2009).

Even before the double crisis hit the country, economic growth, structural diversification, and poverty reduction had been slow. The country faces several economic challenges, including rapidly depleting oil resources, slow economic diversification, fiscally unsustainable oil subsidies, and rapid population growth. Official unemployment rates have risen to around 16 percent in recent years, and 65 percent of the population still resides in rural areas, where dependence on deteriorating natural resources threatens traditional sources of income from agriculture (World Bank 2007). In addition, the country faces severe political tensions, including a civil war in the country's northern province of Saada and a secessionist movement in the south of Yemen.

The objective of this paper is to decompose the effects of the food, fuel, and financial crises and to estimate their combined impacts on growth, agriculture, and poverty in Yemen. Due to the lack of consistent gross domestic product (GDP) figures for 2008 and the first three quarters of 2009 and information on poverty,¹ we use a computable general equilibrium (CGE) model to estimate the impacts of the crises on the Yemeni economy. We link these results to a microsimulation module to assess the impacts of these crises on poverty. Section 2 presents the main channels of impact in the country context of Yemen and discusses potential interlinkages between these channels. Section 3 presents a new dynamic computable general equilibrium (DCGE) model for Yemen and explains the progressive approach to implement the crises scenarios. Section 4 first describes the model's baseline results from 2007 to 2010 and then subsequently adds the food, fuel, and financial crisis impacts to assess the combined impacts on growth and poverty. Section 5 concludes.

¹ The Central Statistics Office (CSO) is in the process of restructuring and rebasing national accounts and other economic indicators.

2. CRISES IMPACT CHANNELS IN YEMEN

Yemen remains relatively insulated from global financial markets, yet the food and fuel crises and the financial crisis may impact the country through several real economy channels. On the macro level, impacts of the food, fuel, and financial crises depend on the economic structure, patterns and balances of trade, balance and composition of the government budget, and the sources of foreign exchange inflows. On the micro level, sources of household incomes and expenditures patterns determine the size and direction of crises impacts. These channels will be the focus of the analysis discussed in the following sections.

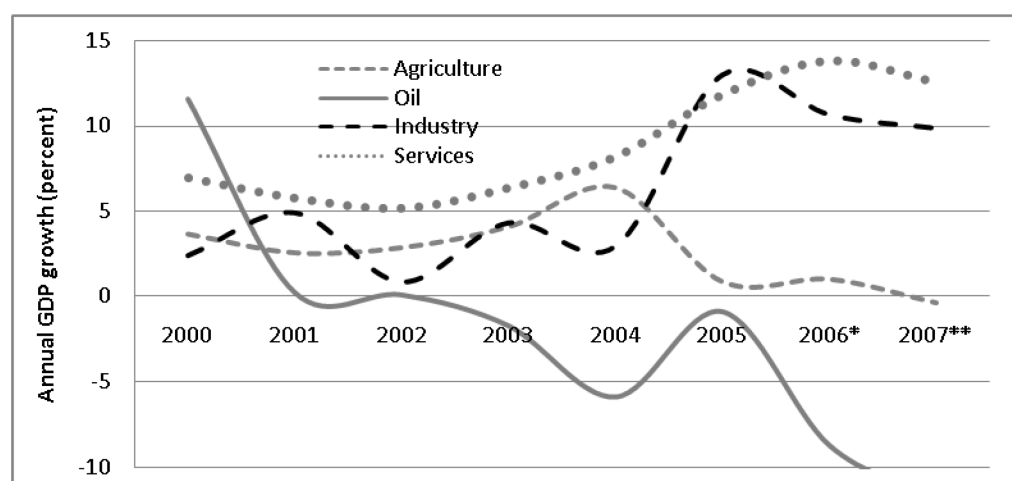
Similar to many other mineral resource-rich countries, Yemen has an economy dominated by the mining sector (oil) and nontradable services; manufacturing and export-oriented services make up a relatively small share of the economy. In 2007, the oil sector accounted for 22 percent of total GDP; services contributed half to GDP; and the remainder was split between construction-dominated industry (15 percent) and agriculture (10 percent) (see Table 2 in Section 4). In the agricultural sector, qat,² fruits, vegetables, and livestock are the most important products in value terms, but cereal production, for which world food prices rose most rapidly during the food crisis, constitutes only 10 percent of value-added agricultural (Breisinger and McCool 2009).

Economic growth in Yemen averaged 3.8 percent during 2000–2006, with service and industrial growth (mainly construction) as the main drivers (Figure 1). This service- and construction-led growth is linked to government spending from oil revenues through both public investments, mostly in urban areas, and recurrent spending. About 30 percent of the workforce is employed with the government, and windfall gains from oil are often associated with rising public sector wages and infrastructure investments, mostly in urban areas. However, this growth model is challenged by declining oil reserves and the lack of new oil finds. Unless new oil fields are discovered, it is estimated that Yemen will run out of oil resources in the next 20 to 30 years, indicating that the oil sector will contract at a speed of 2–3 percent annually. Yemen is likely to become a net oil importer in the next 5 to 10 years even with continued oil production due to rapidly increasing domestic consumption that is highly subsidized (MOPIC 2009). Some of the decline in the oil sector will be compensated by the exploitation of gas that is scheduled to start production in 2010, yet these revenues will be unlikely to balance decreasing oil revenues (EIU 2009).

Agricultural growth has been volatile due to the sector's high dependence on rainfall and the generally harsh natural conditions, especially the increasing scarcity of water. Although total growth in agriculture averaged 3.0 percent between 2000 and 2006, continued rapid population growth has meant no agricultural growth on a per capita basis. Moreover, agricultural growth fell to 1 percent in more recent years since 2004, which further underscores the big challenges facing agriculture in Yemen.

² Qat is an evergreen plant with leaves that are widely used as stimulants in Yemen. The crop contributes about 30 percent to value-added agricultural and uses 40 percent of irrigation water.

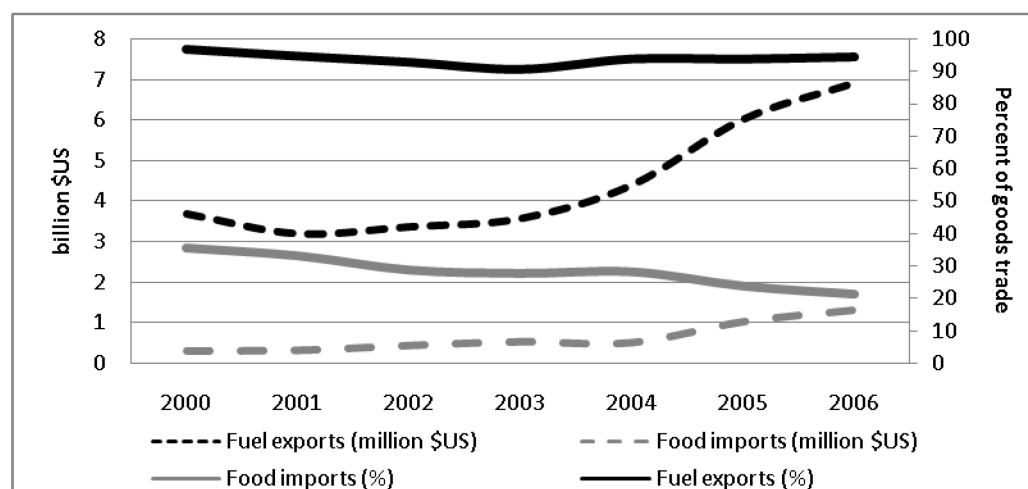
Figure 1. Annual GDP growth rates by sector, 2000–2006



Source: Authors' calculations based on CSO 2007 and 2008.

Yemen's trade patterns make it an interesting case to assess the joint impacts of the food and fuel crises. In terms of exports, Yemen is heavily dependent on oil, which made up 90 percent of the country's total exports in the past decade (Figure 2). The remaining exports are mainly agricultural products including coffee, tobacco, fish, and animal products, as well as some light manufacturing products. In terms of imports, Yemen is one of the countries that is most dependent on food imports in the world. In Yemen, 55 percent of food products consumed are imported, and 90 percent of wheat (the main staple) is imported. Total food imports account for about 20 percent of total imports, other consumer goods account for 10 percent, and the rest of imports are about equally split between capital goods and refined fuel.

Figure 2. Oil and food trade, 2000–2006



Source: Authors' calculations based on World Bank 2009a.

Oil also dominates the government budget and related services. In terms of government revenue, about three-quarters of the budget stems from oil revenues, indicating that swings in world oil prices directly affect the government budget. On the spending side, the fuel subsidy constitutes a big burden for

the government, particularly when oil prices are high.³ Due to the lack of domestic refining capacities, Yemen imports most of the fuel consumed domestically. In 2007, for example, oil subsidies accounted for about one-quarter of government expenditure, almost the same as the spending on public employees' wages and salaries (about 26 percent). Thus, the high costs of fuel subsidies partly offset windfall gains to the government.

Oil constitutes 90 percent of exports and is also the most important source for foreign exchange earnings, contributing about three-quarters to total foreign exchange inflows in 2007 (Figure 3). The rest of the inflows are primarily remittances sent by Yemenis who work abroad, making it an important source of income at both the macro and the household levels (IMF 2009). There is broad agreement that remittances declined in the recent crisis period; the estimated range is –5 percent to –20 percent (MOPIC 2009; IMF 2009; World Bank 2009c). While foreign direct investment (FDI) started to increase recently, the bulk of it is concentrated in the mining sector, traditionally in oil and more recently in the gas sector to develop liquefied natural gas facilities. Other sectors that have received FDI include tourism, real estate, and to a limited extent manufacturing, mainly from Gulf countries (World Bank 2009e). About 1 percent of the government budget, or 75 billion YER, comes from development assistance (ODA in the form of loans and grants, suggesting that a possible crunch in global development aid might not have significant effect in Yemen (EIU 2009). Moreover, the ODI number seems not to include extrabudgetary development assistance in the form of programs and projects. For example, a recent report suggests that the Yemeni government received US\$2 billion in emergency assistance from Saudi Arabia in 2009 (EIU 2009).

Given the government's dependence on oil revenues, fiscal space for stimulus-type measures to cushion negative impacts of the financial crisis and global recession is limited. On the contrary, the government has reportedly cut back on its budget in 2009; different sources estimate the reduction in spending between 10 and 50 percent compared with 2008 levels (MOPIC 2009). Cutbacks include the freeze in replacements of retired government employees and reductions in social spending (MOPIC 2009). These crises-related reductions in public spending are likely to be exacerbated by war-related spending in Yemen's Saada region, which is estimated to cost US\$2–3 million per day.

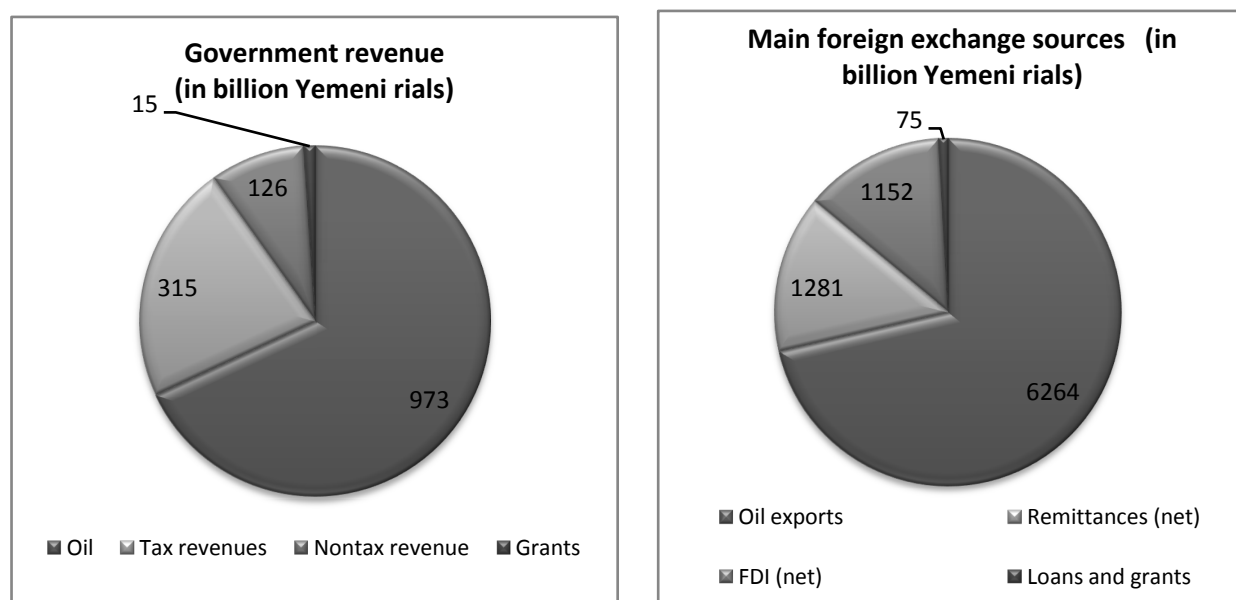
Box 1. Government responses to the food crisis

The Yemeni government has introduced a number of policies and actions specifically to mitigate the adverse effects of soaring food prices on the population. Short-term actions have included training bakeries to produce bread from mixed cereals, standardizing the weight and size of bread loaves, drafting plans to increase the number of beneficiaries of the social welfare fund to reach more than one million, and raising government and staff salaries by US\$15 per month. Midterm actions have included conducting studies on reducing prices and learning from other countries' experiences—such as those of Egypt, which has removed import taxes on staples, increased the amount of assistance to beneficiaries, purchased local cereals from farmers, and encouraged farmers to plant wheat. Planned long-term actions include a focus on reducing wheat and wheat flour imports, building government cereal silos to encourage more imports by the private sector, and encouraging the local production of wheat by supporting local farmers (WFP 2008).

Source: Adapted from Jones et al. 2009.

³ Petrol prices are fixed. One liter of diesel and petrol sells for 35 YER and 60 YER at the pump, respectively.

Figure 3. Share of oil revenue in the government budget



Source: Calculations based on IMF 2009.

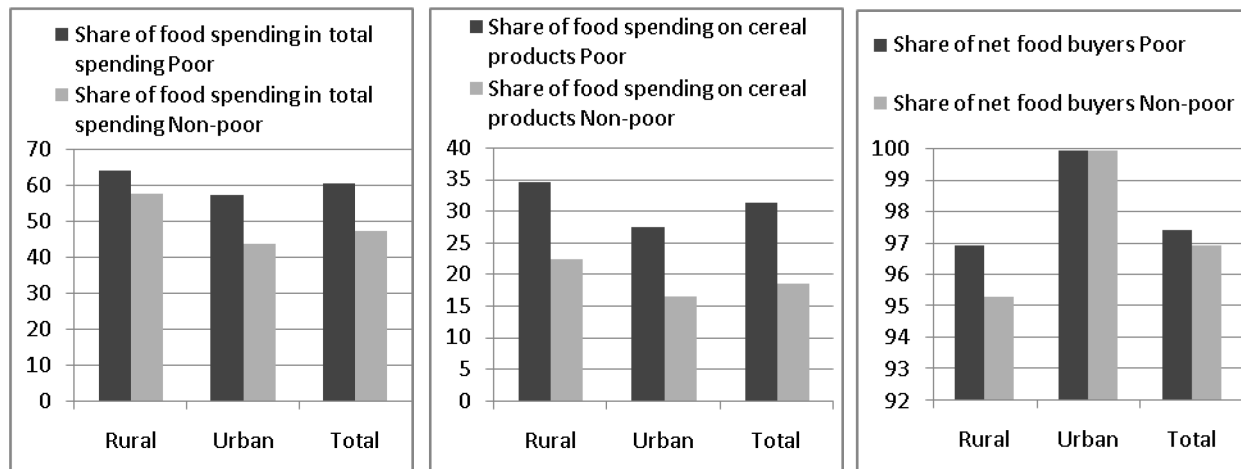
Progress in poverty reduction has been modest when growth is largely oil driven, and 34.8 percent of Yemenis lived below the poverty line in 2006 before the crises hit (World Bank 2007). Poverty among rural households stood at 40.1 percent compared with 20.7 percent for urban households. Moreover, for those households that are not classified as poor but whose income level is very close to the poverty line, vulnerability to falling back into poverty is high. For example, a reduction of per capita income by US\$0.50 per day would increase the number of poor by 15 percentage points (POVCAL 2009), indicating a very high vulnerability to external shocks such as the food, fuel, and financial crises. On the expenditure side, food makes up the largest share of household spending and accounts for more than half of the total household expenditure (Figure 4). As expected, these shares are even higher for poor households, which spend about 60 percent of their income on food—35 percent on cereals alone. However, even households that are not poor spend a significant share of income on food, 58 percent for rural and 44 percent for urban households.

Constrained by climate, water, and other agroecological conditions, the vast majority of Yemeni households are net food buyers, even in rural areas. For the nation as a whole, only 4 percent of rural households are net food sellers. The share among the poor is even lower, as 97 percent of poor rural households are net food buyers. Only 15 percent of the population live in farm households.⁴ As opposed to the dominant role of food consumption, fuel consumption as a share of an average household's total expenditure is low (2 percent) considering that fuel is heavily subsidized in the country. More importantly, with the subsidy in place, potential indirect impacts through increased costs of intermediate inputs and transportation are expected to be low even in times of fuel price spikes.

On the income side, the majority of an average Yemeni household income comes from wage labor and self-employment. Remittances also constitute a relatively large source of income for households: 9 percent of total household income stems from this source, about half of the total going to rural and half to urban households.

⁴ Farm households are defined as households that earn more than 60 percent of their income from agriculture. Calculation is based on the Household Budget Survey 2005/2006.

Figure 4. Poverty and net food position of households



Source: Authors' calculations based on CSO 2007.

In summary, the country-specific examination of the importance of main crises transmission channels indicates that both swings in oil and food prices and changes in remittances are likely to have strong impacts on growth and poverty in Yemen. FDI and ODI inflows are unlikely to be affected by the crises. In the next section we present a model to quantify the impacts from each of the main channels and to analyze their joint effects on growth and poverty.

3. A CGE MODEL TO ASSESS THE CRISIS IMPACTS IN YEMEN

The computable general equilibrium (CGE) model presented in this section captures the major channels through which the food, fuel, and financial crises impact the Yemeni economy and households. The CGE model is dynamic and thus also captures the links between the three crises that occur during several years. To develop a dynamic CGE (DCGE) model for Yemen, we first built a new social accounting matrix (SAM) to represent Yemen's economy in 2007 as the main database for the model.⁵ Major data sources for SAM construction include national accounts and the latest supply-use table from the Central Statistics Organization (CSO), Balance of Payments from the Bank of Yemen (BoY), government budget data from the Ministry of Finance, the 2008 Agricultural Yearbook from the Ministry of Agriculture and Irrigation, and the latest Household Budget Survey (HBS 2005/2006) (CSO 2007).⁶ These data sources are complemented with information from the International Monetary Fund and the World Bank. The SAM is very detailed at the production, commodity, factor, and household levels and includes 65 production sectors (activities), 65 commodities, 15 factors of production, and 12 household types (for a detailed list see Appendix Table A.1). Factors of production include labor according to the skill level (unskilled, semiskilled, and skilled) and employment by the public and private sector. An aggregate version of the SAM (Macro SAM) can be found in Appendix Table A.2.

Major general features of the model are explained in Appendixes B and C; however, several specific features are built in to account for the relatively short-term horizon of the simulation period (2007–2010).

First, to account for the limited options to shift capital from one sector to the next, we assume that most capital is sector specific. Only 10 percent of the total capital is economywide; thus the dynamics in capital formation are limited. Oil capital is fixed and declining at an annual rate of 2.4 percent to account for the declining oil resources. Second, land for most crops, especially perennial crops, is fixed to account for the limited supply responsiveness of the agricultural sector to short-term price shocks. Third, for unskilled and semiskilled labor employed in the private sector, we assume fixed wages; therefore, unemployment rises as a consequence of declining outputs in sectors that employ these labor types. For skilled labor and labor working in the public sector, we assume flexible wages and full employment, implying that in times of recession wages and thus incomes of households fall. In summary, this model setup accounts for the short-term nature of price shocks to assess growth and poverty impacts. Structural change caused by the reallocation of labor and capital is only captured to a limited extent.

The model is calibrated to the new Yemen SAM; that is, the base year of the model is consistent with the structure of the Yemeni economy in 2007. We then develop a baseline (or business-as-usual) scenario in which the Yemeni economy continues to grow along its 2000–2006 growth path at the aggregate-sector level (agriculture, industry, services) between 2007 and 2010. The baseline also takes into account the shrinking oil production and thus serves as a counterfactual to show what would have happened in the absence of the food, fuel, and financial crises. In this baseline scenario as well as in all other scenarios, we assume that the nominal exchange rate is fixed in the short term to account for the quasi peg of the Yemeni rial (YER) to the U.S. dollar. However, the real exchange rate is an endogenous variable, which is affected by changes in domestic and world prices. The other exogenous variables, besides the nominal exchange rate, include government consumption, transfers to households, foreign inflows, population growth, and hence growth of the workforce, which all grow exogenously according to their historic trends in recent years. Investments are savings driven, and savings grow proportionally to household incomes. The government budget is flexible, which means that the government can adjust to changes in revenues and spending by increasing or decreasing the budget deficit. At the sector level, total

⁵ Special thanks for excellent research assistance from Christen McCool, who processed the HBS 2005/2006 for all household income and expenditure information that is used in the SAM.

⁶ Data quality and availability can be challenging in Yemen since the data management system in Yemen is in a time of transition with major overhauls of the national accounting system. However, one of the strengths of social accounting matrixes is to reconcile different data sources, which can help to improve data estimates.

factor productivity (TFP) increases exogenously to account for the differential growth patterns across sectors.

The DCGE model also links to a microsimulation model, which allows for the endogenous estimation of growth impacts on poverty reduction. All HBS sample households are included in the microsimulation model, and their total expenditures and expenditures on each commodity or commodity group are linked to each of the 12 representative households included in the DCGE model according to their locations. The linkages between the DCGE and microsimulation models allow for the analysis of microimpact of the changes in representative households' consumption induced by changes in their incomes, changes in market prices, and other factors. The endogenous changes derived from the DCGE model for the 12 representative households are used to recalculate consumption expenditure of their corresponding households in the survey dataset. New levels of total consumption expenditures are recalculated based on individual households' budgets; and the new poverty rates for each region, rural and urban, and the national total are obtained by comparing expenditure levels (in real terms) to the official poverty line defined for HBS.

Consistent with the changes in the recent years, we model the food and fuel crisis in 2008 and the financial crisis in 2009 by designing the three sets of scenarios. The scenarios follow the general price trends observed from 2007 to 2010, when food and oil prices rose dramatically in 2008, fell back in 2009, but have stayed above 2007 levels throughout 2009 and into 2010. The change in government spending and remittances related to the financial crisis follows trends observed in the country during 2009 and then returns to precrisis annual growth levels in 2010.

The first set of scenarios focuses on the food and fuel crises and is modeled as a one-time increase in world food and oil/fuel prices. As in most standard single-country CGE models, world prices for imports and exports are exogenous while imports and exports are endogenous in response to changes in the world prices relative to the domestic prices for similar goods. In the scenario combining both the food and the fuel crises, we exogenously increase the 2008 world prices for food products by 20–100 percent and oil and fuel prices by 20 percent in the model, and the prices fall to the projected 2009 levels and remain at these levels thereafter (see Table 1 for the level of price shock in the scenario and Appendix Figure A.1 for the actual world price change). To decompose the potentially differential impacts of the food and fuel crises, we also consider two counterfactual scenarios that reflect the food crisis only and the fuel crisis only. In the fuel crisis only and in the food and fuel joint scenarios we also consider higher government spending as a consequence of windfall gains from the oil boom; that is, a –20 percent annual growth rate for government consumption spending is assumed based on information from MOPIC, whereas in a normal year without shock, the growth rate is 3.8 percent.

The second set of scenarios analyzes the impacts of the financial crisis and related global recession. As discussed in Section 2, we focus mainly on the trade and remittances channels. Similar to the food and fuel crisis scenarios, we consider both the isolated and joint effects in the simulations. The first financial crisis scenario (Scenario 4 in Table 1) is designed to capture the trade effect only by lowering the world prices for all the goods that Yemen imports or exports. Specifically, the 2009 world food prices are assumed to fall by 14–33 percent, and prices for major consumer and investment goods fall by 10 percent compared with 2008 levels. These price changes are as projected and consistent with the drop in prices under the food and fuel crises scenario in 2009. In addition, under this scenario the government spending is reduced by 20 percent (instead of increasing by 3.8 percent in the baseline) in 2009 due to the sharp drop in oil revenues. The second financial crisis scenario (Scenario 5 in Table 1) reflects the drop of remittances received by Yemeni households from their overseas relatives, which is modeled as a 10 percent decline in foreign inflows received by the households in 2009. The joint effect of these two scenarios constitutes Scenario 6 in Table 1, the financial crisis scenario.

Table 1. Model scenarios and assumptions

Growth rate/changes in selected exogenous variables			
	Export/import prices (% difference from previous year)	Government consumption (% change from previous year)	Remittances (% change from previous year)
First set of scenarios			
<i>Food and fuel crises: Changes in 2008</i>			
Scenario 1: Fuel crisis only	20, oil price only	5.0	5.0
Scenario 2: Food crisis only	20–100, food prices only*	3.8	5.0
Scenario 3: Food and fuel crises		5.0	5.0
<i>Food and fuel crises: Changes in 2009</i>		as in Scenario 6	
Second set of scenarios			
<i>Financial crisis: Changes in 2009</i>			
Scenario 4: Trade	–14 to –33 for food prices* –10 for consumer and investment good prices	–20.0	5.0
Scenario 5: Remittances		3.8	–10.0
Scenario 6: Financial crisis	–14 to –33 for food prices* –10 for consumer and investment good prices	–10.0	–10.0
Third set of scenarios:			
<i>Food, fuel, and financial crises: Changes in 2008–2009</i>			
Scenario 7: Combined	Combined (Scenarios 3 & 6)		

Source: Information for foreign transfers from IMF 2009; government consumption follows 2000–2006 growth trend; TFP and world price changes from IMF 2009, World Bank 2009b, and IFPRI staff estimates.

Note: *Cereals and dairy products only. Population grows at 3 percent annually (UN 2009) and is the same across all scenarios.

Finally, we combine the food and fuel crises with the financial crisis in an additional scenario (Scenario 7 in Table 1) to assess the overall effect of this series of crises on growth and poverty between 2008 and 2010. Table 1 presents the shocks imposed on the model for each of the scenarios described above.

4. IMPACTS OF THE FOOD, FUEL, AND FINANCIAL CRISES

Under the model's baseline, the Yemeni economy grows along its past trend at an average of 3.7 percent annually from 2007 to 2009. The baseline captures the continued decline in oil revenues and the negative growth in the sector's GDP (−2.2 percent annually), together with growth rates of the agricultural sector between 2.2 and 3.0 percent, higher growth of the nonoil industry (8.6–11.0 percent) led by growth in the gas and construction sectors, and average annual growth of 5.0 to 5.6 percent in the services sectors (Table 2, top panel). The decline in oil output negatively affects GDP growth, resulting in a GDP growth rate reduction to 3.6 percent in 2009. The gas sector grows through investments in 2009 and commencing gas production in late 2009 and accelerates overall growth to 4.1 percent in the baseline; however, this will only be a one-time effect and is expected to abate from 2011 on. In addition, it is expected that the production of gas will not be able to compensate for the declining oil revenues.

On the expenditure side of GDP, private consumption remains the dominant factor, constituting 59.6 percent of GDP in 2007 and 57.0 percent by 2010 (Table 2, bottom panel). The decline in the private consumption share of GDP is mirrored in the increase in the investment and government consumptions shares, while share of exports in the GDP falls due to declining oil output. While the trade deficit remains constant by design, as a ratio to GDP it rises between 2007 and 2010.

The poverty analysis is conducted by linking a microsimulation model with the DCGE model. Accordingly, with modest change in per capita GDP in the baseline, the poverty rate in rural and urban areas remains relatively constant, and the national poverty rate increases only slightly from 34.8 percent in 2006 to 35.6 percent by 2010. The modest increase in the national poverty rate is led by the rise in urban poverty (from 20.7 percent in 2007 to 23.9 percent in 2010), while the poverty rate for rural households as a whole stays constant at 40.1 percent due to generally weaker linkages between oil revenues and rural household incomes.

Table 2. Baseline growth for selected economic indicators (comparable with 2000–2006 historical average)

	2007	2007	2008	2009	2010
GDP	Share	Annual growth (%)			
GDP (million YER)	4,640	3.9	3.9	3.6	4.1
Agriculture	9.5	3.0	3.0	2.3	2.2
Oil	22.3	−2.2	−2.2	−2.2	−2.2
Nonoil industry	14.8	9.8	9.8	9.5	11.0
Services	53.5	5.6	5.6	5.0	5.5
GDP by expenditure share	100	100	100	100	100
Private consumption/GDP	59.6	58.5	58.5	57.8	57.0
Investment/GDP	30.8	32.3	32.3	33.3	34.4
Government consumption/GDP	16.5	16.5	16.5	16.5	16.5
Exports/GDP	35.1	33.7	33.7	32.4	31.1
Imports/GDP	−42.0	−40.9	−40.9	−40.0	−39.1
Consumer Price Index (CPI)		1.00	0.98	0.95	0.91

Source: Yemen DCGE model results.

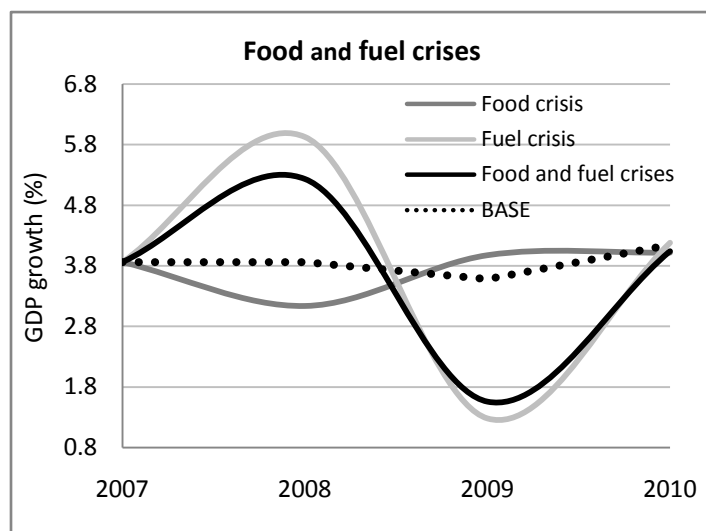
In summary, the results of the baseline simulations show that the model captures past sector-level and poverty trends well. We therefore use this model to assess the impacts of the food, fuel, and financial crises that hit Yemen consecutively between 2008 and 2009.

Impacts of the Food and Fuel Crises

We first focus on the aggregate impacts of the food and fuel crises on overall growth, agricultural growth, and poverty in Yemen. Consistent with the observation between 2000 and 2007, the model simulation shows a positive growth effect of the oil price spike under the fuel-crisis-only scenario. Total GDP growth accelerates to 5.9 percent in 2008, up from a 3.8 percent annual average in the baseline. Growth is driven by the oil sector and the related increase in public spending on construction and services. On the contrary, when only the food crisis is considered, without the oil price increase, the GDP growth rate decelerates to 3.1 percent in 2008 before recovering in 2009 to the precrisis level. The growth decline caused by the food crisis can be primarily explained by increased food consumption costs and lowered nonfood spending at given income levels, which in turn negatively affect growth in nonfood sectors. On the other hand, the agricultural sector benefits from high food prices as a result of the food crisis. However, the agricultural supply response to higher prices is only a short-term phenomenon. When food prices stop increasing in 2009, agricultural growth falls sharply from its peak in 2008.

The third scenario examines the joint impacts of the food and fuel crises, which occurred quasi-simultaneously in 2008. As demonstrated in Figure 5, the food and fuel crises have opposite effects on growth, and the overall impact is thus an S-shaped curve that is smoother than the sharp S-curve of the fuel crisis alone. However, the positive growth effect of the oil crisis is stronger than the negative effect of the food crisis. The overall effect of the two crises on GDP is thus positive: Annual growth in GDP accelerates to 5.2 percent, up from 3.8 percent in the baseline, indicating Yemen is a net beneficiary of the joint crisis. The result of this scenario is close to preliminary GDP growth rate estimates by the CSO (2009), and slightly higher than the World Bank's estimate of 4.4 percent for 2008 (World Bank 2009e).

Figure 5. Growth impacts of the food and fuel crises



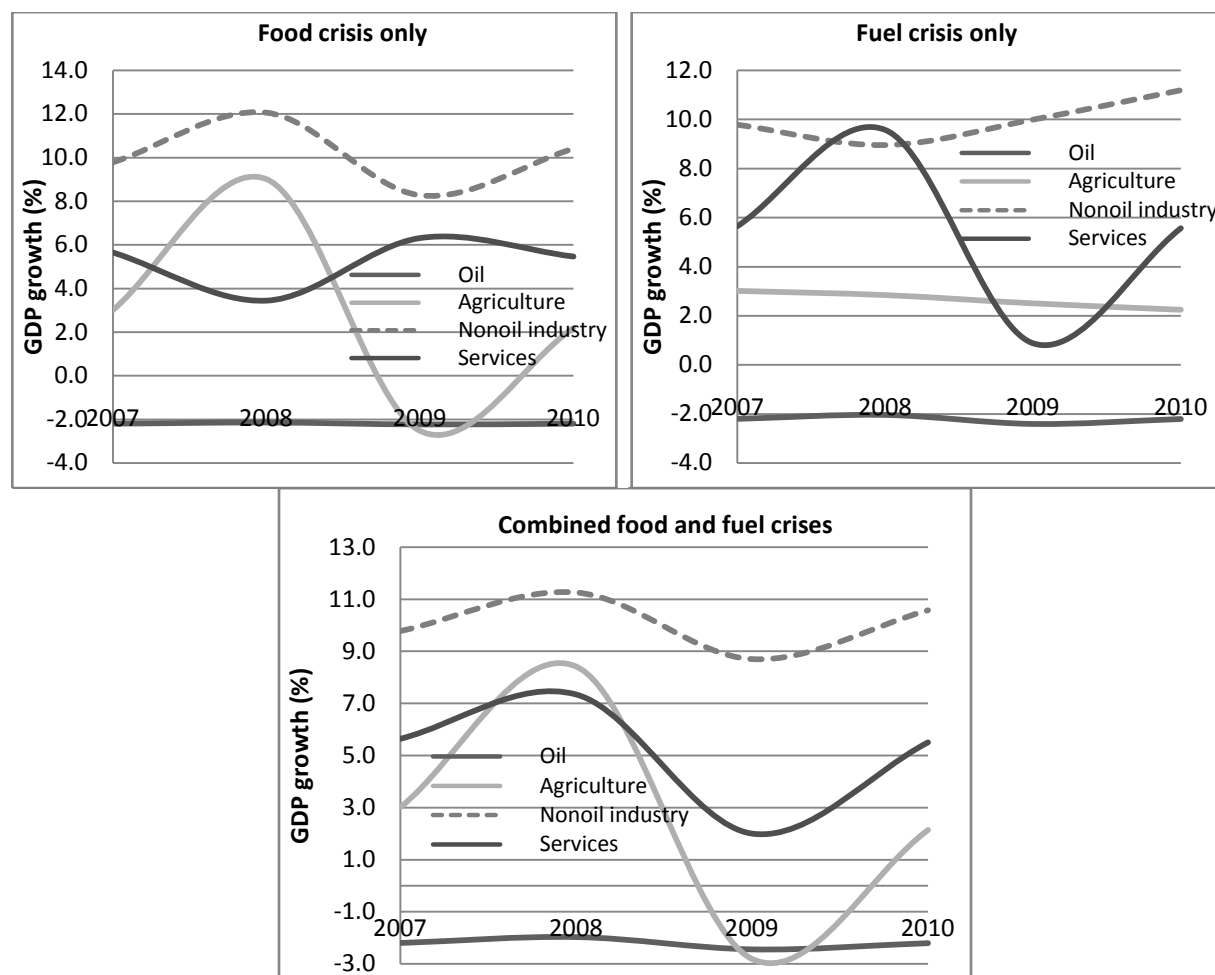
Source: Yemen DCGE model results.

The growth effect of the joint food and fuel crisis is positive, yet the effects at the sector and household levels may be very different. Thus, we first examine the joint effect on growth in the agricultural, oil, nonoil, and service sectors and then discuss the differential poverty impact between rural and urban households.

The oil price spike and associated windfall gains to the government drives growth in the service sector, while growth in the nonoil industry sector is modest under the food and fuel crises scenario. Growth in the nonoil industry output is led by the construction sector, which benefits from an increase in investment (Figure 6). Under the food-crisis-only scenario, the agricultural sector is the main beneficiary

of high world cereal prices. High world cereal prices cause a relative increase in all domestic food prices and thus accelerate agricultural growth to 8.4 percent. However, higher food prices also cause a reduction in consumer spending on nonfood items, which hits services especially hard. The two main sector-level impacts, the oil-driven service sector boom and the agricultural sector growth driven by the food price spike, are only temporary and cannot be sustained. Once food and fuel prices fall in 2009, both sectors see sharp drops in growth before they return to precrisis levels.

Figure 6. Growth impacts of the food and fuel crises by sector



Source: Yemen DCGE model results.

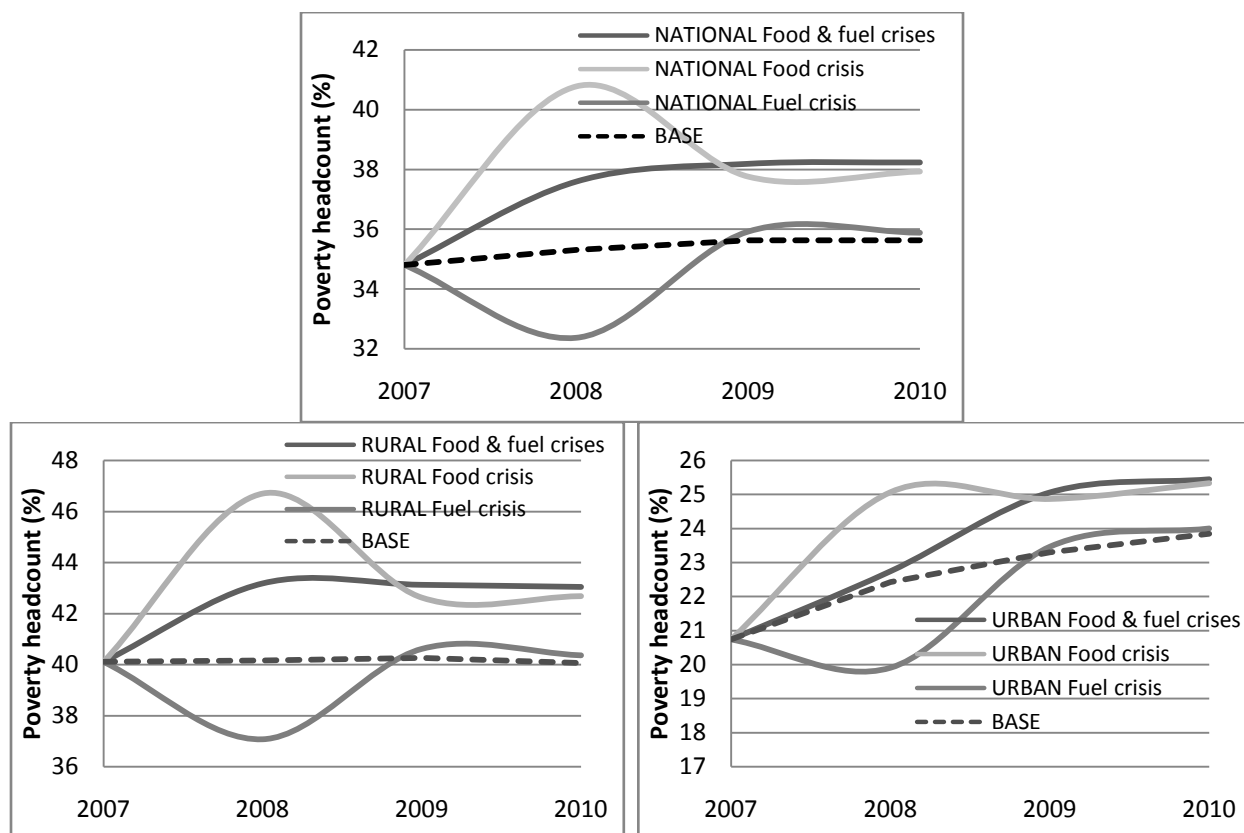
While the agricultural sector benefits from a scenario of high food prices alone, the joint impacts of the food and fuel crises on the sector can be characterized as volatile growth caused by the fluctuations in world food prices. For the oil, service, and industrial sectors, growth accelerates only in the crisis year of 2008. With the assumption of a one-year price spike in 2008, growth in these nonagricultural sectors declines in 2009 and returns to the precrisis levels in 2010.

Assessing the poverty impacts of the two crises is a major focus of this paper. The last household survey was conducted in 2005/2006, and previous attempts to update poverty estimates for Yemen have focused on the food crisis only. A simple poverty-updating exercise based on this survey shows that the food crisis might have caused poverty to increase in Yemen by 6 percentage points (World Bank 2009d).

Our model results confirm this estimation and show that the food crisis has much stronger and negative effects on the welfare of households than the fuel crisis (Figure 7). The dominant factor behind

this result is the fact that the majority of Yemeni households are net buyers of food, which accounts for the largest share of their consumption budget, and the country as a whole heavily depends on food imports. Under the food-crisis-only scenario, the national poverty rate rises to 40.8 percent in 2008 from an estimated 34.8 percent in 2006. Both rural and urban poor households suffer under the food crisis: The poverty rate of urban households goes up 4.4 percentage points to 25.1 percent, and the rural poverty rate increases to 46.7 percent, from 40.1 percent in 2006.

Figure 7. Poverty impacts of the food and fuel crises



Source: Yemen DCGE model results.

On the other hand, the oil price hike under the fuel-crisis-only scenario has limited effects on poverty. The main channels that cause poverty to change are the oil-related government transfers and other spending. The rise in government spending benefits urban households directly through additional public sector jobs and higher-wage incomes of public sector employees. On the other hand, benefits to rural households are more limited and mainly stem from increased direct transfer payments. Although there is evidence that existing social transfers are not well targeted to the poor, data from the HBS 2005/2006 indicates that about half of government transfers go to rural households.

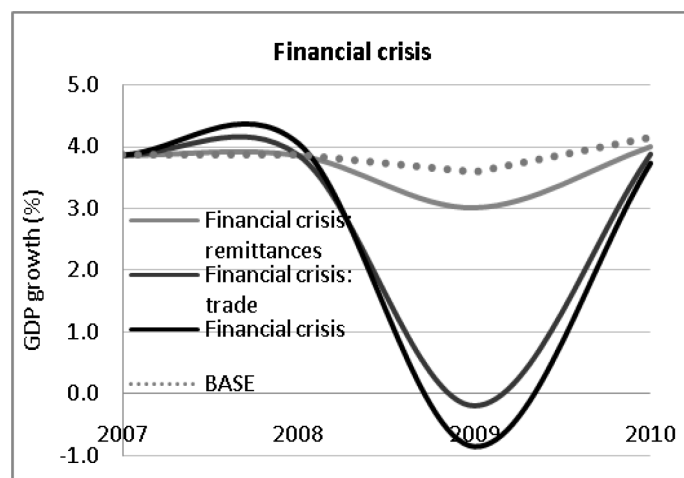
Since rural households benefit little from the oil windfalls and most of the poor live in the rural areas, the effect of the joint food and fuel crisis on the poor is strongly dominated by the food crisis. In the joint crisis scenario (Scenario 3), the national poverty rate rises to 37.6 percent in 2008 and remains at higher-than-baseline levels thereafter. Thus, contrary to the recovery of overall economic growth in 2009, the poverty rates for both rural and urban households remain at 3.0 and 4.3 percentage points above baseline levels, respectively. This finding strongly suggests that continued high food prices make it especially hard for the poor to recover from food price shocks despite the relatively quick rebound of economic growth.

In this precarious situation, when the poor were struggling to recover from the impacts of the food and fuel crises, the next crisis hit the global economy and Yemen. In the next section, we examine the isolated effects of the financial crisis first, before joining this crisis with the previous two to estimate the joint effect of the crises.

Impacts of the Financial Crisis

Yemen is relatively insulated from global financial markets, and thus the financial crisis mainly affects Yemen through real economy channels. Although Section 2 of this paper suggests two major channels through which the financial crisis might affect an economy like Yemen's, the modeling analysis seems to indicate that the trade effect is the dominant factor (Figure 8).

Figure 8. Growth impacts of the financial crisis

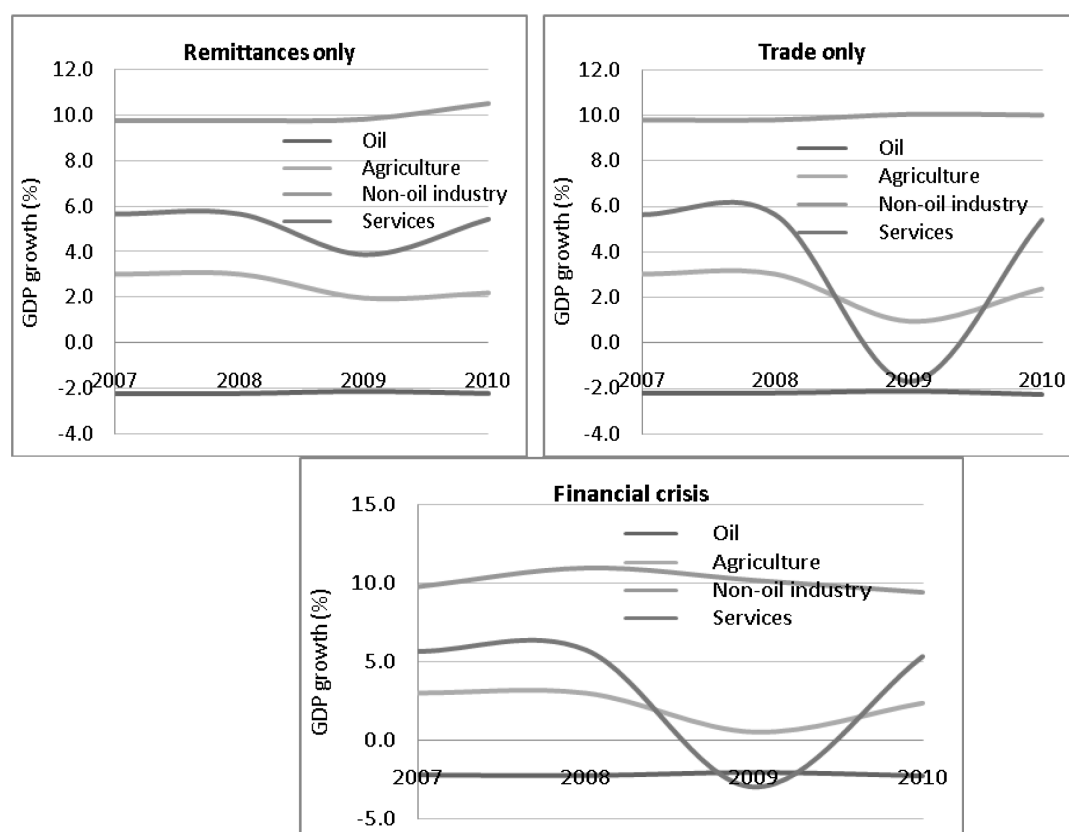


Source: Yemen DCGE model results.

The negative impacts of falling world commodity prices are simulated in the trade-only scenario (Scenario 4) in which the export side effect is strongly dominated by the sharp reduction in the value of oil exports. The performance of other major export goods such as coffee, tobacco, and fruits remains stable, given that their prices only modestly change in 2009 (and thus we did not consider them in the model). Moreover, the decline in oil exports together with the related additional exogenous decline in government spending (as reported by government sources) causes a sharp contraction of other sectors, especially services and agriculture. The reduction in exports thus dominates the positive impacts due to lowered cost for imports during the financial crisis in Yemen.

Under the trade-only financial crisis scenario, GDP growth drops to -0.2 percent in 2009; while in the remittance-only financial crisis scenario (Scenario 5), GDP growth slows to 3.0 percent in 2009. The relatively small growth effect from the reduction in remittances can be explained by the relatively small share of remittances in GDP and the modest size of the shock. Remittances constitute about 10 percent of household incomes, and thus the 10 percent decline causes a 1 percent reduction in aggregate household income as a direct effect. This reduction in household incomes, however, generates second- and third-round indirect effects on the economy. Most importantly, reduced consumer spending affects growth at the sector level, including agriculture (Figure 9).

Figure 9. Growth impacts of the financial crisis by sector



Source: Yemen DCGE model results.

In Scenario 6, the financial crisis is modeled by jointly reducing trade and remittances. All sectors are hurt in this scenario, yet the degree of impact varies across sectors. The service sector is hit the most due to its strong linkages with the government sector (public services constitute a large share of total services), which is heavily dependent on oil revenues. The decline in government recurrent spending⁷ causes a decline in public sector employees' real-wage income, either through a lower-wage rate or cut of government staff. While agriculture and nonoil industries are relatively more resilient to the financial crisis, growth in agriculture falls to 0.5 percent in 2009 from 3.6 in the same year's baseline. Growth in nonoil industries drops by only 0.5 percentage points compared with the previous year, mainly caused by investments in the gas sector and production starting in late 2009. Thus, the sector is not affected by the crisis and compensates for growth losses in other subsectors in the nonoil category during 2009–2010. However, due to its relatively small size, the gas sector is unlikely to reverse negative effects from the decrease in oil export value. It is also unlikely to compensate for the weak performance in the service and agricultural sectors.

These growth results under the model's financial crisis scenario are consistent with the projection of Economist Intelligence Unit (EIU 2009, 14), in which GDP is predicted to fall to 5,665 billion YER in 2009 from 5,735 billion YER in 2008 in nominal prices.⁸ More optimistic earlier projections were often

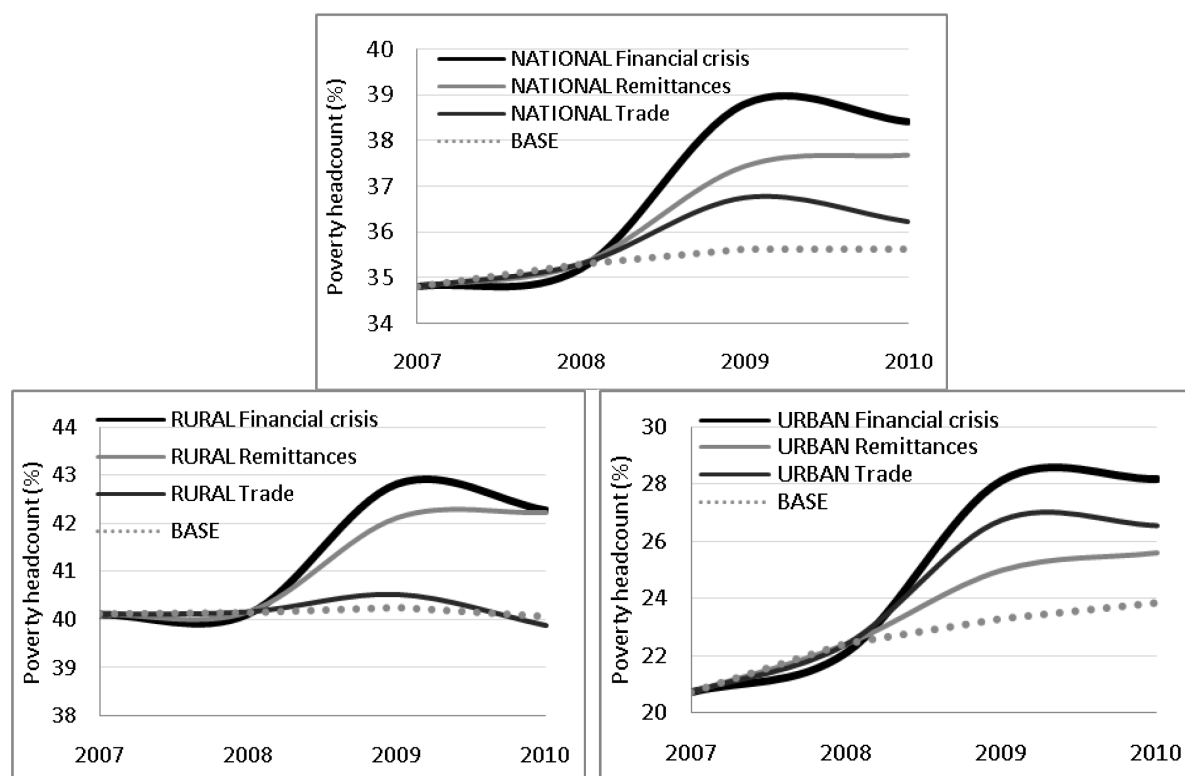
⁷ To capture the declines in government revenue due to declining oil exports, government spending other than savings, which is an exogenous variable available in the model, is assumed to fall by 10 percent in 2009.

⁸ There is some debate on the calculation of changes in real GDP between 2008 and 2009. There is agreement that nominal GDP fell and also that the consumer price index (CPI) increased. Deflating nominal GDP by the CPI would thus lead to a sharp contraction of the economy. However, due to Yemen's distorted economic structure, it is theoretically possible that nominal GDP falls, consumer prices rise, and real GDP rises. This is because the GDP deflator is based on GDP shares (where oil plays an important role), whereas the CPI is based on consumption shares (where food and consumer goods are much more important).

based on the assumption that gas exports commence in early 2009, which did not occur in reality. The International Monetary Fund, for example, projected 7.7 percent growth for 2009 annual growth in its joint staff report in March 2009.

Although there are different growth projections due to different assumptions on the impacts of the financial crisis and uncertainty on price deflators, most experts agree that the poverty rate has gone up as a consequence of the financial crisis. Results from our DCGE model show that poverty indeed increases from 34.8 percent in the baseline to 38.8 percent under the financial crisis scenario. These poverty effects at the national level are dominated by the remittances channel as opposed to the growth impact, which is dominated by the trade effect. Under the financial crisis scenario, the poverty rate increases by a modest 1.5 percentage points due to the trade channel, while the rate of people living in poverty increases by 2.1 percentage points as a consequence of the cut in remittances (Figure 10). Urban households are hit especially hard by the financial crisis. The sharp reduction in government spending and related job cuts in public services and reduced government transfers cause the urban poverty rate to rise by 6.0 percentage points in 2009, compared with a more modest increase of 2.7 percentage points in rural areas.

Figure 10. Poverty impacts of the financial crisis



Source: Yemen DCGE model results.

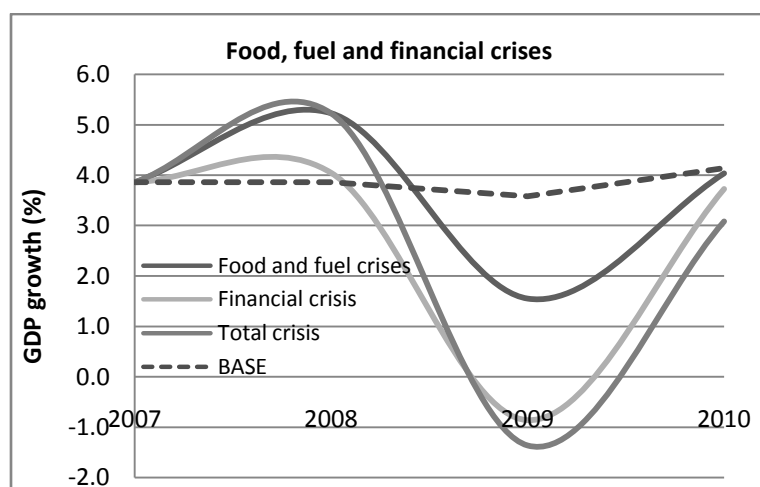
Joint Impacts of the Food, Fuel, and Financial Crises

The previous scenarios have considered the impacts of both the food and fuel crises and the financial crisis sequentially but independently. In this section we present the result of a triple crisis scenario that joins the impacts of the food and fuel crisis with the financial crisis. In the absence of any official statistical or other type of data from the country for the last two years (2008 and 2009), this triple crisis scenario can be viewed as an estimation of growth and poverty trends in Yemen after 2007.

So, for example, if oil prices fall (by more than output) and nonoil prices rise, then it is theoretically possible that the CPI rises but the GDP deflator falls. If this fall in the GDP deflator is substantial, real GDP might grow even though nominal GDP falls.

Given that the food and fuel crises occurred mainly in 2008 and the financial crisis mainly in 2009, the total crisis scenario displays a much more realistic picture of growth dynamics in recent years as compared with looking at each period individually (Figure 11). Without the financial crisis in 2009, the effect of the food and fuel crises on growth would have quickly phased out in the years after 2008. However, the onset of the financial crisis in 2009 has altered growth recovery and leads to a negative growth in GDP in 2009. Thus, the financial crisis, because it followed the food and fuel crises, not only slows down growth recovery but also makes the recovery after 2009 more difficult. Even under the assumption that the world returns to precrisis conditions and no further shock in 2010, growth remains at a level well below precrisis situation. The GDP growth rate in 2010 is only 3.1 percent, compared with 3.8 percent in the baseline's 2010 growth outcome.

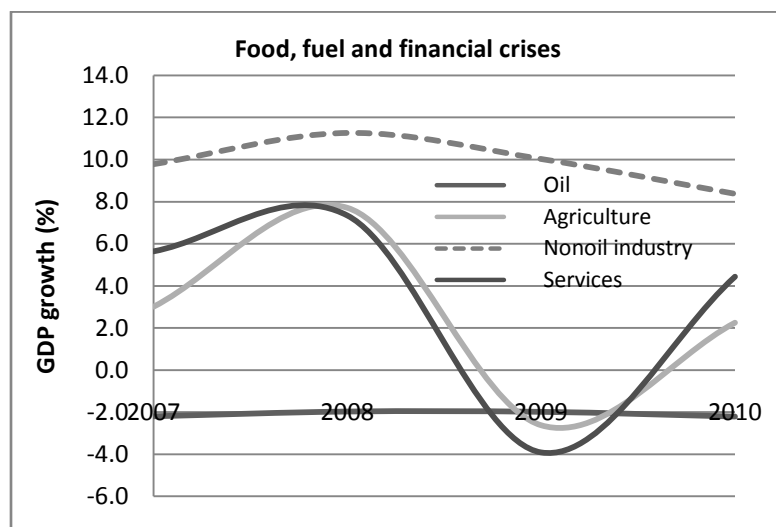
Figure 11. Growth impacts of the food, fuel, and financial crises



Source: Yemen DCGE model results.

At the sector level, the continued crisis hits services and agriculture especially hard, while the effect on the nonoil industry is relatively modest (Figure 12). This outcome is largely due to certain factors specific for Yemen, especially the kicking in of liquefied natural gas production in 2009 and 2010.

Figure 12. Growth impacts of the food, fuel, and financial crises by sector

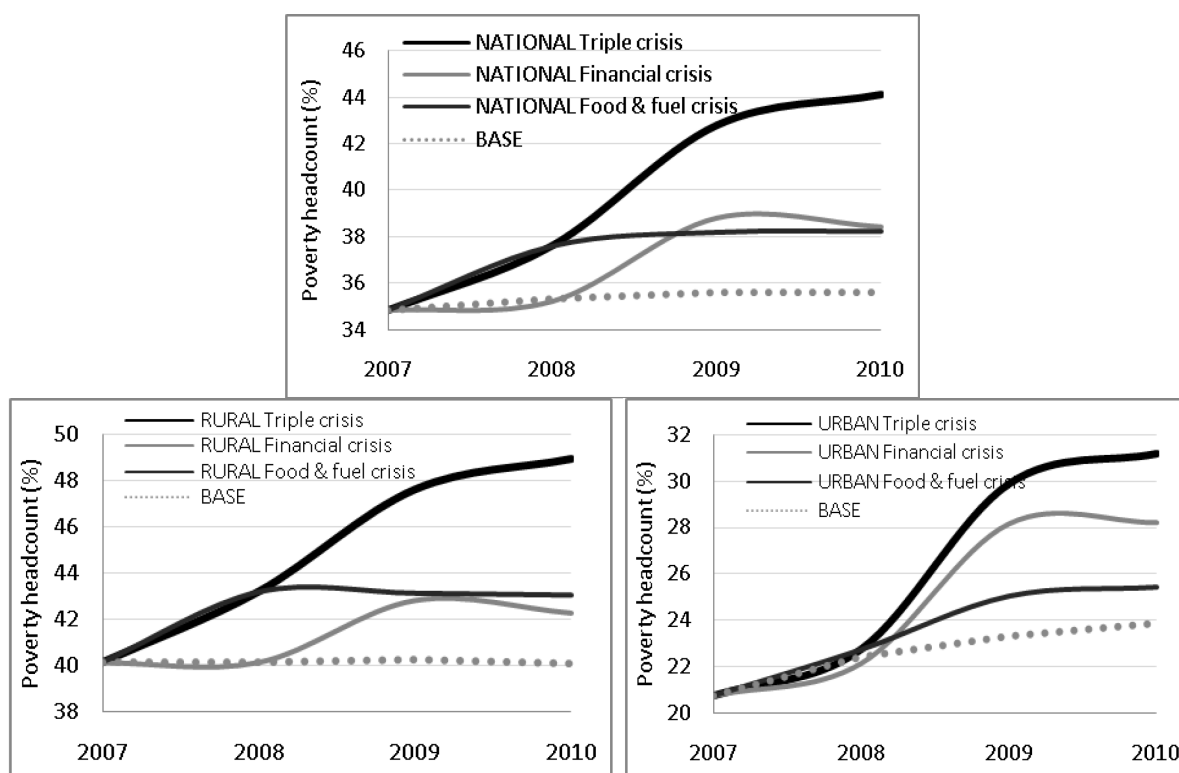


Source: Yemen DCGE model results.

The triple crisis hit the poor doubly hard, especially rural households (Figure 13). Poverty was high during the food crisis, yet it is reaching new heights during the financial crisis. Had the financial crisis not occurred, the increase in poverty levels would have slowed due to falling food prices. However, instead of recovering, rural households were hit hard by a drop in remittances, and urban households, by both the drop in remittances and declining oil revenues.

The additional shock of the financial crisis further raises the poverty rate to 42.8 percent in 2009, 8 percentage points above precrisis levels. The poverty increase is severe for both rural and urban households (Figure 13). Poverty in rural areas increases to 47.6 percent, making almost every second rural inhabitant poor. In urban areas, poverty increases from 21.6 to 29.9 percent, thus pushing almost one-third of the urban population below the poverty line.

Figure 13. Poverty impacts of the triple crisis



Source: Yemen DCGE model results.

5. CONCLUSIONS

Many developing countries have been hard hit by a series of crises during 2007–2009, yet analytical evidence of their impact on development and how they might have affected each other remains scarce. This paper has attempted to shed light on these questions, thereby making contributions to both the understanding of crises interlinkages in general and the estimation of country-level postcrisis poverty rates for Yemen. Because the last household survey was conducted before the crises and there is uncertainty about the growth estimates, this study also serves as an estimation of growth and poverty trends between 2007 and 2009–2010, which are based on a consistent economic model. To capture the impacts of the triple crisis, we have considered changing world market prices, a drop in remittances, government spending, and trade. Yemen-specific additional features of our crisis modeling include the general decline in oil production and additional gas-sector investments and production in the country in 2009 and 2010.

We first decompose the impacts of the food crisis and the fuel crisis and show that the growth impacts are converse and countercyclical. While high oil prices have accelerated economywide growth, high food prices have slowed growth mainly through reduced private nonfood consumption. Oil-driven growth dominates the joint growth effect in the crisis year of 2008. However, this oil-driven growth has not been pro-poor; poverty under the combined food and fuel crisis rises sharply for both rural and urban households.

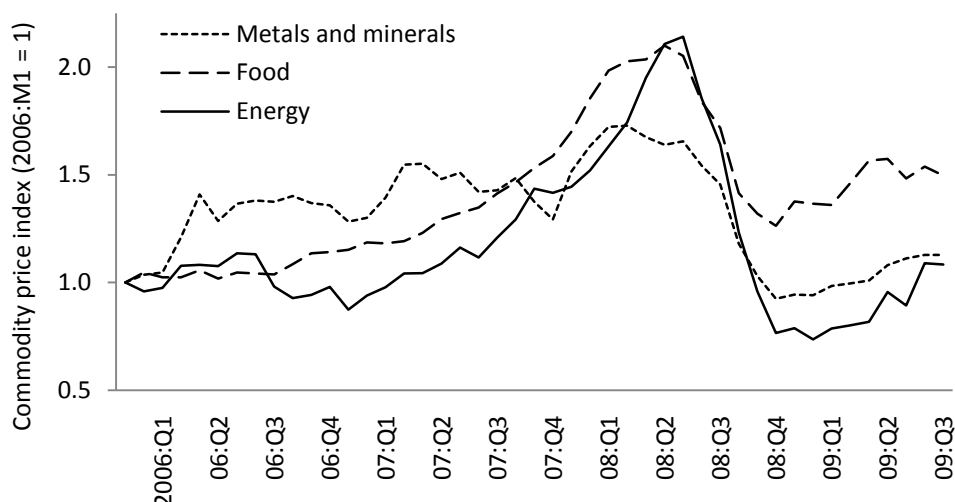
Despite the lack of direct financial market links, real economy effects from the financial crisis lead to negative growth in the absence of any additional fiscal measures. The sharp drop in growth is dominated by the drop in oil prices and related decrease in government spending. Poverty effects of the financial crisis differ between rural and urban households. While urban households are hit hard by the collapse in trade and government spending, the net effect from trade channel impacts is neutral for rural households, mainly due to the positive effects of falling food prices. However, the drop in remittances affects both rural and urban households with the result of a sharp overall rise in poverty.

On the sector level, results show that oil-dependent and poor countries like Yemen are especially vulnerable to global crises. The reduction in oil revenues and related spending cannot be compensated by lower prices for imports of food and consumer and investment goods. Although agriculture often stabilizes economic growth and household incomes in terms of crisis, this role of the sector is limited in Yemen due to the relatively low share of the sector in GDP (10 percent) and the large share of net food-buying households in Yemen (97 percent).

The impacts of the financial crisis should not be seen in isolation from the preceding crises. While growth rebounds relative quickly after each shock, recovery from falling into poverty is a much slower process. Poverty effects from one crisis to the next add up and compound each other. In the case of Yemen, poverty increases from precrisis levels of 34.8 percent to 37.6 percent in 2008 and 42.8 in 2009. These estimates can be considered conservative, because we do not account for the ongoing war in Saada province and the related displacement of people and public spending cuts, severe electricity shortages, and major floods in Hadramout governorate that recently hit the country.

APPENDIX A: SUPPLEMENTARY TABLES AND FIGURE

Figure A.1. World commodity prices, 2006–2009



Source: Authors' calculations using World Bank (2009b). Note: Q stands for quarter.

Table A.1. SAM and Model Disaggregation

Activities/commodities		Factors of production
Agriculture	Industry (cont.)	Labor
Sorghum	Other processing	Private sector, unskilled
Maize	Fish processing	Private sector, semiskilled
Millet	Textiles and clothing	Private sector, skilled
Wheat	Leather and shoes	Public sector, unskilled
Barley	Wood	Public sector, semiskilled
Other grains	Paper	Public sector, skilled
Bananas	Printing	Capital
Grapes	Oil refining	Capital
Mangoes	Chemicals	Oil capital
Citrus fruits	Fertilizer and pesticides	Land
Other fruits	Nonmetals	Land temperate highlands
Potatoes	Metals	Land dry highlands
Onions	Machinery	Land Red Sea and Tihama
Tomatoes	Other manufacturing	Land Arab Sea
Other vegetables	Electricity	Land internal plateau
Pulses	Water	Land desert
Coffee	Construction	Households*
Sesame	Services	Urban
Cotton	Trade	Temperate highlands
Qat	Hotels and restaurants	Dry highlands
Tobacco	Transport & communication	Red Sea and Tihama
Camel	Business services	Arab Sea
Cattle	Health	Internal plateau

Table A.1. Continued

Activities/commodities		Factors of production
<i>Agriculture</i>	<i>Industry (cont.)</i>	<i>Labor</i>
Chicken	Education	Desert
Goats & sheep	Public services	<i>Rural</i>
Fishery	Other services	Temperate highlands
Forestry		Dry highlands
<i>Industry</i>		Red Sea and Tihama
Oil		Arab Sea
Gas		Internal plateau
Other mining		Desert
Beverages		
Bread		<i>Other accounts</i>
Other cereal-based food		Enterprise
Dairy products		Government
Vegetable oil		Direct taxes
Sugar, processed		Sales taxes
Camel meat		Import tariffs
Beef meat		Savings & investment
Poultry		Rest of world
Goat & sheep meat		

Table A.2. 2007 Macro SAM for Yemen

	Activities	Commodities	Labor	Capital	Enterprise	Household	Government	Direct tax	Sales tax	Import tax	Invest	ROW	Total
Activities		7,115											7,115
Commodities	2,477					2,642	722				1,340	1,545	8,725
Labor	2,779												2,779
Capital	1,860												1,860
Enterprise				1,668			158					76	1,903
Household			2,779	191	58		126					285	3,439
Government					1,099			153	-289	44		271	1,278
Direct tax					80	73							153
Sales tax		-289											-289
Import tax		44											44
Savings					257	725	262					97	1,340
ROW		1,855			409		10						2,274
Total	7,115	8,725	2,779	1,860	1,903	3,439	1,278	153	-289	44	1,340	2,274	

Note: ROW = rest of the world

APPENDIX B: EXTENDED MODEL DESCRIPTION⁹

The ability to capture intersector synergies, trade-offs, and linkages has made general equilibrium models an important tool in analyzing the impacts of growth accelerations. The DCGE model is an economywide, multisectoral model that solves simultaneously and endogenously for both quantities and prices of a series of economic variables. On the supply side, the model defines specific production functions for each economic activity. Assumptions that are made before calibrating the model to the data include constant returns-to-scale technology with constant elasticity of substitution (CES) between primary inputs. This is a fundamentally necessary assumption for the model to reach a general equilibrium solution. For the substitution between primary and intermediate inputs in the production functions we assume a Leontief technology.

The demand side of the CGE model is dominated by a series of consumer demand functions. This demand system is derived from well-defined utility functions. In our model, the consumer demand functions are solved from a Stone-Geary type of utility function in which the income elasticity is not at unity, and hence, the marginal budget share of each good consumed departs from its respective average budget share. Similar to other general equilibrium models, consumer income that enters the demand system is an endogenous variable in our model. Income generated from the primary factors employed in the production process is the dominant income source for consumers, while the model also considers incomes from abroad (as remittance received) or from the government (as direct transfers).

The DCGE model explicitly models the relationship between supply and demand, which determines the equilibrium prices in domestic markets. To capture the linkages between the domestic and international markets, the model assumes price-sensitive substitution (imperfect substitution) between foreign goods and domestic production. Although the linkages between demand and supply through changes in income (an endogenous variable) and productivity (often an exogenous variable) are the most important general equilibrium interactions in an economywide model, production linkages also occur across sectors through the intermediate demand and competition for primary factors employed in production sectors.

Investments affect production over time, and productivity growth is also a gradual process. Capturing this dynamic process is a key component of a DCGE model. Given the complexity of the model setup in terms of its large number of production sectors in both agriculture and nonagriculture, and its highly disaggregated agricultural production and household groups across subnational regions, it is unrealistic to develop a fully intertemporal general equilibrium model for this study.¹⁰ Thus, we use a recursive dynamic model. With this model setup, the dynamics occur only between two periods at a time. Consumption smoothing along the growth path as well as the intertemporal investment and saving decisions are not taken into account. Instead, private investment and hence capital accumulation are determined by a Solow type of saving decision in which savings are proportional to the income and not endogenously solved from a Ramsey type of intertemporal utility function. Population growth, land expansion at the subnational and national levels, and productivity growth are all exogenously determined. Mathematic presentation and corresponding model parameters and variables are listed in Appendix B.

To capture different agricultural production patterns and technologies at the subnational level, the SAM and DCGE models further disaggregate agricultural activities into six agroecological zones (temperate highlands, dry highlands, Red Sea and Tihama, Arabian Sea, internal plateau, desert) using district-level production data. Workers in the model can migrate between sectors and regions, although agricultural land remains within each region's agricultural sectors. The skilled labor force grows more slowly than the rest of the workforce (unskilled and semiskilled).

The SAM and DCGE models further disaggregate households into subnational groups in both rural and urban areas. Information on income distribution from labor and land derived from HBS

⁹ The model description is based on Breisinger, Diao, and Thurlow 2009.

¹⁰ An intertemporal general equilibrium model in literature is often with relatively aggregated economic structure. See Diao et al. (2005) for the growth linkage analysis in the case of Thailand as an example.

2005/2006 is used to calibrate the initial income distribution of the model. In general, returns to land, labor, and capital employed in agricultural production at the regional level go to the region's rural household group, and returns to capital employed in nonagricultural production and wage income of skilled labor go to urban households. Rural households also earn labor income from nonagricultural activities, which can occur either in the rural (i.e., rural nonfarm) or in the urban areas. Income elasticities of households' demand functions are estimated using consumption expenditure data from HBS 2005/2006.

Both the SAM and the DCGE models include a government account, which collects direct taxes from households and indirect taxes from imports, exports, and domestic sales, and then supplements its revenues with foreign grants from development partners that are used for investment expenditures. Information on government revenues and expenditures was provided by the Ministry of Finance and Economic Planning.

APPENDIX C: CORE MODEL EQUATIONS

Table C.1. Mathematic presentation of DCGE model—sets, parameters, and variables

Symbol	Explanation	Symbol	Explanation
Sets			
$a \in A$	Activities	$c \in CEN(\subset C)$	Commodities not in CE
$a \in ALEO(\subset A)$	Activities with a Leontief function at the top of the technology nest	$c \in CM(\subset C)$	Aggregate imported commodities
$c \in C$	Commodities	$c \in CMN(\subset C)$	Commodities not in CM
$c \in CD(\subset C)$	Commodities with domestic sales of domestic output	$c \in CX(\subset C)$	Commodities with domestic production
$c \in CDN(\subset C)$	Commodities not in CD	$f \in F$	Factors
$c \in CE(\subset C)$	Exported commodities	$h \in H(\subset INSDNG)$	Households
Equation parameters			
cpi	Consumer price index	$mps0l_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates
$cwts_c$	Weight of commodity c in the CPI	pwe_c	Export price (foreign currency)
ica_{ca}	Quantity of c as intermediate input per unit of activity a	$shif_{if}$	Share for domestic institution i in income of factor f
$icd_{cc'}$	Quantity of commodity c as trade input per unit of c' produced and sold domestically	$shii_{ii'}$	Share of net income of i' to i ($i' \in INSDNG'$; $i \in INSDNG$)
$ice_{cc'}$	Quantity of commodity c as trade input per exported unit of c'	ta_a	Tax rate for activity a
$icm_{cc'}$	Quantity of commodity c as trade input per imported unit of c'	$tins_i$	Exogenous direct tax rate for domestic institution i
$inta_a$	Quantity of aggregate intermediate input per activity unit	$tins0l_i$	0–1 parameter with 1 for institutions with potentially flexed direct tax rates
iva_a	Quantity of aggregate intermediate input per activity unit	tm_c	Import tariff rate
mps_i	Base savings rate for domestic institution i	tq_c	Rate of sales tax

Table C.1. Continued

Symbol	Explanation	Symbol	Explanation
Equation parameters, continued			
α_a^a	Efficiency parameter in the CES activity function	δ_{cr}^t	CET function share parameter
α_a^{va}	Efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor f in activity a
α_c^{ac}	Shift parameter for domestic commodity aggregation function	γ_{ch}^m	Subsistence consumption of marketed commodity c for household h
α_c^q	Armington function shift parameter	θ_{ac}	Yield of output c per unit of activity a
α_c^t	CET function shift parameter	ρ_a^a	CES production function exponent
β^a	Capital sectoral mobility factor	ρ_a^{va}	CES value-added function exponent
β_{ch}^m	Marginal share of consumption spending on marketed commodity c for household h	ρ_c^{ac}	Domestic commodity aggregation function exponent
δ_a^a	CES activity function share parameter	ρ_c^q	Armington function exponent
δ_{ac}^{ac}	Share parameter for domestic commodity aggregation function	ρ_c^t	CET function exponent
δ_{cr}^q	Armington function share parameter	η_{fat}^a	Sector share of new capital
ν_f	Capital depreciation rate		
Exogenous variables			
$fsav$	Foreign savings	qg_c	Government consumption demand for commodity
mps_i	Marginal propensity to save for domestic nongovernment institution (exogenous variable)	$qinv_c$	Base-year quantity of private investment demand
pwm_c	Import price (foreign currency)	$transfr_{if}$	Transfer from factor f to institution i
$qdst_c$	Quantity of stock change	$wfdist_{fa}$	Wage distortion factor for factor f in activity a
qfs_f	Quantity supplied of factor		
Endogenous variables			
AWF_{ft}^a	Average capital rental rate in time period t	$QINTA_a$	Quantity of aggregate intermediate input
$IADJ$	Investment adjustment factor	$QINT_{ca}$	Quantity of commodity c as intermediate input to activity a
EG	Government expenditures	$QINV_c$	Quantity of investment demand for commodity
EH_h	Consumption spending for household	QM_{cr}	Quantity of imports of commodity c
EXR	Exchange rate	PA_a	Activity price (unit gross revenue)
$GSAV$	Government savings	PD_c	Demand price for commodity produced and sold domestically
QF_{fa}	Quantity demanded of factor f from activity a	PE_{cr}	Supply price for commodity produced and sold domestically
QH_{ch}	Quantity consumed of commodity c by household h	$PINTA_a$	Export price (domestic currency)
QHA_{ach}	Quantity of household home consumption of commodity c from activity a for household h	PK_{ft}	Aggregate intermediate input price for activity a

Table C.1. Continued

Symbol	Explanation	Symbol	Explanation
Endogenous variables, continued			
PM_{cr}	Unit price of capital in time period t	QX_c	Aggregated quantity of domestic output of commodity
PQ_c	Import price (domestic currency)	$QXAC_{ac}$	Quantity of output of commodity c from activity a
PVA_a	Composite commodity price	$TRII_{ii'}$	Transfers from institution i' to i (both in the set INSDNG)
PX_c	Value-added price (factor income per unit of activity)	WF_f	Average price of factor
$PXAC_{ac}$	Aggregate producer price for commodity	YF_f	Income of factor f
QA_a	Producer price of commodity c for activity a	YG	Government revenue
QD_c	Quantity (level) of activity	YI_i	Income of domestic nongovernment institution
QE_{cr}	Quantity sold domestically of domestic output	YIF_{if}	Income to domestic institution i from factor f
QQ_c	Quantity of goods supplied to domestic market (composite supply)	K_{fat}^a	Quantity of new capital by activity a for time period t
QVA_a	Quantity of (aggregate) value-added		

Table C.2. Mathematic presentation of DCGE model—model equations

Production and price equations

$$QINT_{ca} = ica_{ca} \cdot QINTA_a \quad (1)$$

$$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca} \quad (2)$$

$$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf} \cdot QF_{fa})^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}} \quad (3)$$

$$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot QVA_a \cdot \left(\sum_{f \in F'} \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf} \cdot QF_{fa})^{-\rho_a^{va}} \right)^{-1} \cdot \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf})^{-\rho_a^{va}} \cdot (QF_{fa})^{-\rho_a^{va}-1} \quad (4)$$

$$QVA_a = iva_a \cdot QA_a \quad (5)$$

$$QINTA_a = inta_a \cdot QA_a \quad (6)$$

$$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a \quad (7)$$

$$QXAC_{ac} = \theta_{ac} \cdot QA_a \quad (8)$$

$$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac} \quad (9)$$

$$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}-1}} \quad (10)$$

$$PXAC_{ac} = PX_c \cdot QX_c \cdot \left(\sum_{a \in A'} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-1} \cdot \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}-1} \quad (11)$$

$$PE_{cr} = pwe_{cr} \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c} \quad (12)$$

$$QX_c = \alpha_c^t \cdot \left(\sum_r \delta_{cr}^t \cdot QE_{cr}^{\rho_c^t} + (1 - \sum_r \delta_{cr}^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}} \quad (13)$$

$$\frac{QE_{cr}}{QD_c} = \left(\frac{PE_{cr}}{PD_c} \cdot \frac{1 - \sum_r \delta_{cr}^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t-1}} \quad (14)$$

$$QX_c = QD_c + \sum_r QE_{cr} \quad (15)$$

$$PX_c \cdot QX_c = PD_c \cdot QD_c + \sum_r PE_{cr} \cdot QE_{cr} \quad (16)$$

$$PM_{cr} = pwm_{cr} \cdot (1 + tm_{cr}) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c} \quad (17)$$

Table C.2.Continued

Production and price equations

$$QQ_c = \alpha_c^q \cdot \left(\sum_r \delta_{cr}^q \cdot QM_{cr}^{-\rho_c^q} + (1 - \sum_r \delta_{cr}^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}} \quad (18)$$

$$\frac{QM_{cr}}{QD_c} = \left(\frac{PD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \sum_r \delta_{cr}^q} \right)^{\frac{1}{1+\rho_c^q}} \quad (19)$$

$$QQ_c = QD_c + \sum_r QM_{cr} \quad (20)$$

$$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PD_c \cdot QD_c + \sum_r PM_{cr} \cdot QM_{cr} \quad (21)$$

$$cpi = \sum_{c \in C} PQ_c \cdot cwtsc \quad (22)$$

Institutional incomes and domestic demand equations

$$YF_f = \sum_{a \in A} WF_f \cdot wfdist_{fa} \cdot QF_{fa} \quad (23)$$

$$YIF_{if} = shif_{if} \cdot YF_f \quad (24)$$

$$YI_i = \sum_{f \in F} YIF_{if} + \sum_{i' \in INSDNG'} TRII_{ii'} + transfr_{i \text{ gov}} \cdot cpi + transfr_{i \text{ row}} \cdot EXR \quad (25)$$

$$TRII_{ii'} = shii_{ii'} \cdot (1 - mps_{i'}) \cdot (1 - tins_{i'}) \cdot YI_{i'} \quad (26)$$

$$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{ih} \right) \cdot (1 - mps_h) \cdot (1 - tins_h) \cdot YI_h \quad (27)$$

$$PQ_c \cdot QH_{ch} = PQ_c \cdot \gamma_{ch}^m + \beta_{ch}^m \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma_{c'h}^m \right) \quad (28)$$

$$QINV_c = IADJ \cdot qinv_c \quad (29)$$

$$EG = \sum_{c \in C} PQ_c \cdot qg_c + \sum_{i \in INSDNG} transfr_{i \text{ gov}} \cdot cpi \quad (30)$$

$$YG = \sum_{i \in INSDNG} tins_i \cdot YI_i + \sum_{c \in CMNR} tm_c \cdot pwm_c \cdot QM_c \cdot EXR + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c + \sum_{f \in F} YF_{gov f} + transfr_{gov \text{ row}} \cdot EXR \quad (31)$$

System constraints and macroeconomic closures

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + qg_c + QINV_c + qdst_c \quad (32)$$

$$\sum_{a \in A} QF_{fa} = QFS_f \quad (33)$$

$$YG = EG + GSAV \quad (34)$$

Table C.2. Continued

System constraints and macroeconomic closures	
$\sum_{r \in CMNR} pwm_{cr} \cdot QM_{cr} = \sum_{r \in CENR} pwe_{cr} \cdot QE_{cr} + \sum_{i \in INSD} trnsfr_{i row} + fsav$	(35)
$\sum_{i \in INSDNG} mps_i \cdot (1 - \overline{tins_i}) \cdot YI_i + GSAV + EXR \cdot fsav = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$	(36)
Factor accumulation and allocation equations (applies to capital only)	
$AWF_{f,t}^a = \sum_a \left[\left(\frac{QF_{f,t}}{\sum_{a'} QF_{f,t}^{a'}} \right) \cdot WF_{f,t} \cdot wfdist_{f,t} \right]$	(37)
$\eta_{f,t}^a = \left(\frac{QF_{f,t}}{\sum_{a'} QF_{f,t}^{a'}} \right) \cdot \left(\beta^a \cdot \left(\frac{WF_{f,t} \cdot wfdist_{f,t}}{AWF_{f,t}^a} - 1 \right) + 1 \right)$	(38)
$\Delta K_{f,t}^a = \eta_{f,t}^a \cdot \left(\frac{\sum_c PQ_{c,t} \cdot qinv_{c,t}}{PK_{f,t}} \right)$	(39)
$PK_{f,t} = \sum_c PQ_{c,t} \cdot \frac{qinv_{c,t}}{\sum_{c'} qinv_{c',t}}$	(40)
$QF_{f,t+1} = QF_{f,t} \cdot \left(1 + \frac{\Delta K_{f,t}^a}{QF_{f,t}} - \nu_f \right)$	(41)
$QFS_{f,t+1} = QFS_{f,t} \cdot \left(1 + \frac{\sum_a K_{f,t}^a}{QFS_{f,t}} - \nu_f \right)$	(42)

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